J Risk Uncertain (2011) 42:233–261
DOI 10.1007/s11166-011-9115-3

Dopamine receptor genes predict risk preferences, time preferences, and related economic choices

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Published online: 5 April 2011

Abstract Outside of economics, researchers have recently identified genetic predictors of "sensation-seeking" that have been linked to risky and impulsive behaviors. We examine the implications of these genetic polymorphisms for economic behavior. Our analysis indicates that the 7-repeat allele of the DRD4 gene that regulates dopamine uptake in the brain predicts risk-taking and time preferences in economic experiments that allow for ambiguity, losses and discounting. These genetic polymorphisms can also be used to directly predict financial choice patterns that are consistent with previous findings in the behavioral genetics literature.

Keywords Risk · Ambiguity · Loss · Discounting · Dopamine · Genetics

JEL Classification C91 · D14 · D81 · D87 · G11

To be predictive, theoretical and empirical models of behavior must assume that some of the etiological arguments are exogenous. In economics, the tradition

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is to assume that the exogenous primitives are agent preferences (Stigler and Becker 1977). Attitudes towards risk and time, for example, are thought to not change "capriciously" and are modeled as being modulated through the institutional environment to cause people to choose one action over another. However, what determines the distribution of these preferences in the population? Why are some people relatively risk averse and patient compared to others, and are these preferences stable?

Indeed, considerable variation has been revealed in individual attitudes towards risk (Donkers et al. 2001) and time (Harrison et al. 2002) and there is some evidence that suggests that these preferences change in response to environmental influences (Anderson et al. 2008; Sahm 2007; Krupka and Stephens 2009). While the variation in these preferences can be explained to some degree by demographics (e.g., Barsky et al. 1997), and there have been a few recent advances in identifying neurological and biological predictors of preferences like cognitive ability (Burks et al. 2009) or prenatal exposure to testosterone (Garbarino et al. 2011), economists have yet to identify robust exogenous sources of variation in these preferences. This suggests that economists may have stopped too soon in their search for the primitives of behavior. If we dig just a little deeper we might find factors that, although they may interact with the environment, are much more plausibly exogenous and can predict the observed variation in attitudes toward risk and time. For that matter, with a little economic intuition to guide our search, we might be able to directly see how these factors affect choices.

Recent developments in behavioral genetics suggest this will be a good place for economists, who are so inclined, to start digging. Insights from the biosciences can further elucidate the combined influences of human biology (as exogenous primitives) and socio-cultural contextualization in new models of economic behavior. Whether researchers use the classic twin study methodology[1] to infer the general heritability of traits (Bouchard and Propping 1993) or look for direct associations between traits and specific genes (Plomin et al. 2009), the field of behavioral genetics is flourishing. One example of this literature, with particular relevance to our research presented here, comes from Stoel et al. (2006) who examine the extent to which "sensation-seeking", the need for varied, novel and complex sensations, is inherited from one generation to the next. By comparing the expression of this trait in identical (monozygotic) twins, fraternal (dizygotic) twins, and their other siblings, the authors decomposed the observed variation into individual and shared environmental components in addition to a genetic component estimated to be as high as 60% for males.

Recently, this research has moved closer to the domain of economics by examining the heritability of gambling (Eisen et al. 1998), ultimatum game

[1] Which has some history within economics (e.g., Taubman 1976).

responder behavior (Wallace et al. 2007) and cooperation in the trust game (Cesarini et al. 2008). Indeed, there are now studies that examine the extent to which the variation in risk attitudes can be accounted for by genetic factors (Cesarini et al. 2009; Zhong et al. 2009). While the twin study method has begun to influence the economic literature, the parallel approach of linking specific genetic loci to the phenotypic expression of economic behavior has yet to be fully exploited. Our primary contribution is to show that certain genes that influence dopamine reception in the brain can be linked to experimental measures of risk and time preference and financial choices.

In the next section we provide reasons for exploring genes that regulate neural activity in the limbic region of the brain. We then describe our procedures for gathering the experimental, survey, and genetic data. In our experiment we ask participants to choose among binary lotteries to assess their attitudes towards risk. To measure their time preferences, the participants are asked to choose between a series of sooner but smaller or later and larger payoffs. The point at which one moves from choosing the later option to the sooner option gives us a sense of the rate at which one discounts future rewards. At the end of the experiment we asked the participants to fill out an extensive survey that included questions about their finances such as whether they tended to use debt instead of credit cards or used automatic procedures to avoid overdraft fees. At the very end of the experiment our participants gave us saliva samples from which we gathered the needed genetic information.

Our experiment is comprehensive in that we not only gather baseline risk data (as in Kuhnen and Chiao 2009 or Dreber et al. 2009), we elicit time preferences (similar to Eisenberg et al. 2007a although our instrument is incentivized) and include other measures to examine the interaction between variation in dopaminergic activity and how observed preferences change when the risky choices become ambiguous or involve losses, and the time horizon on the discounting choice is extended. Our study is also novel because in addition to gathering a variety of demographic control variables, our survey collects information on financial choices that corroborate our experimental results.

Our analysis has two parts. We first examine the correlations between dopamine receptor genes and our experimental estimates of risk and time preferences. Here we find that genotypes are strong predictors of within subject differences in our measures of observed risk and time preferences. Those participants who carry the 7-repeat DRD4 allele (as opposed to the 4-repeat allele) are more likely to increase the amount of risk they incur when the outcomes become ambiguous or when potential losses are allowed compared to the risky baseline. In addition, 7-repeats (our shorthand for those participants who carry the 7-repeat allele) are significantly more likely to demonstrate preferences which are time-inconsistent, however, in the opposite sense of the standard quasi-hyperbolic formulation. Instead of treating their future selves more patiently than their current selves, 7-repeats become less patient when choices are pushed further into the future.

We also show that genotypes can directly predict financial choice behavior. Consistent with previous findings on sensation-seeking detailed in the next section, we find that 7-repeat individuals make choices that appear more impulsive, risky and short-sighted relative to their 4-repeat counterparts. For example, we find that 7-repeats are 20% less likely to have overdraft protection on their checking accounts and 21% less likely to pay the balance on their credit cards each month. There is some hope, however, that the 7-repeats are sophisticated enough to try to counteract their bad habits—they are also 13% more likely to take advantage of automatic deduction procedures to pay their bills.

We conclude by initiating a discussion of how a simple modification of the standard economic paradigm for choice that accounts for differences in one's ability to process dopamine may be useful because it organizes many of our results, is parsimonious, simple and makes testable predictions for future experiments.

1 Why Dopamine?

Dopamine is a neurotransmitter that has been associated with the mesocorticolimbic reward circuitry (or pleasure system) in the brain. Dopamine, when released, provides feelings of joy that become associated with the triggering thoughts or acts. As such, dopamine provides reinforcement for certain behaviors, particularly those associated with the expectation of reward. Dopamine receptor alleles variably modulate the binding of the neurotransmitter and, therefore, regulate the intensity of the experienced sensation. Figure 1 illustrates the dopamine projection system in the human brain. Midbrain dopamine neurons, the main source, are located in the ventral tegmental area and innervate those areas which have been linked to the anticipation of, cognition of and appetite for rewards: the striatum, the prefrontal cortex and the nucleus accumbens (Schultz 1999). For our purposes, it is important to note that previous research predicts that certain aspects of personality such as sensation-seeking and novelty-seeking (i.e., being impulsive, or exploratory) may be influenced by the dopaminergic links in the brain (Cloninger et al. 1993) and that this system has also been linked to inconsistent time preferences (McClure et al. 2004). More generally, mesolimbic dopaminergic reward has been linked to the reinforcement of appetitive stimuli such as gambling and addictive drug use (Comings et al. 2001; Alcaro et al. 2007).

Specific genes code for the function of different dopamine receptors (i.e., D1–D5). We are particularly interested in one of these genes, DRD4, which produces receptors in the limbic system, the prefrontal cortex, and the striatum which has some role in executive function. Because these receptors exist in brain regions that are responsible for motivation, cognition, and emotion and the battle between the three, we posited that this particular gene would be the most promising candidate for phenotypic expression as behaviors that are the result of the tradeoffs between rewards, risk and impatience.

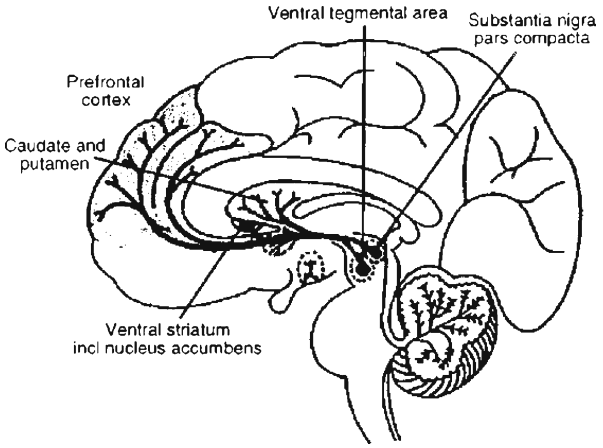


Fig. 1 Overview of the projection territories of midbrain dopamine neurons. Cell bodies of dopamine neurons are located mainly in the pars compacta of substantia nigra and the medially adjoining ventral tegmental area. Their axons project mainly to the striatum (caudate nucleus, putamen), ventral striatum including nucleus accumbens, and frontal cortex (dorsolateral, ventrolateral and orbital prefrontal cortex). Dopamine is released from axon terminals with impulses and influences neurons in these structures. Our experiments investigate the impulse activity at the level of dopamine cell bodies. Source: Schultz (1999)

The allelic variation of DRD4, samples of which we gather, is slightly complex because alleles differ in the number of times a segment of the gene repeats itself (generally between 2 and 11 times). The most common polymorphisms include either the 4-repeat allele (carried by approximately three-quarters of the population) or the 7-repeat allele. The presence of the "longer" repeating alleles (7 or more) is thought to be associated with reduced sensitivity to dopamine and the need for relatively more stimulation to provoke the same internal reward.

Because possessing at least one allele of 7-repeats or longer (7R+) has been linked to novelty-seeking (Noble et al. 1998) and other risky behaviors like sexual intercourse at a younger age (Eisenberg et al. 2007b) or pathological gambling (Perez de Castro et al. 1997) we hypothesized that 7-repeats would behave less risk aversely in our baseline risk task as they have been shown to do elsewhere (Kuhnen and Chiao 2009; Dreber et al. 2009). However, we also sought to add to our knowledge by including new measures to see if this relative risk seeking spanned domains in which only gains were possible, losses were possible and the odds were more ambiguous. Additionally, given the established links between attention deficit hyperactivity disorder and DRD4 (Swanson et al. 2007) and the previous discounting work of Kobayashi and Schultz (2008), we hypothesized that 7-repeats might also be generally less patient and, to extend these results, perhaps even more likely to discount future outcomes quasi-hyperbolically.

Table 1 A summary of the participants and the results

	Overall (N = 140)		No 7-repeat allele (N = 86)		7-repeat allele present (N = 51)	
Age	22.500	(9.118)	22.670	(9.189)	21.235	(7.493)
I(Female)	0.521	(0.501)	0.500	(0.503)	0.549	(0.502)
I(White)	0.728	(0.446)	0.663	(0.475)	0.823	(0.385)
I(Non-student)	0.107	(0.310)	0.116	(0.322)	0.059	(0.238)
I(Finished College)	0.114	(0.319)	0.116	(0.322)	0.078	(0.271)
I(Household income < $25k)	0.128	(0.336)	0.174	(0.382)	0.059	(0.238)
I(Household income > $150k)	0.321	(0.469)	0.244	(0.432)	0.431	(0.500)
Risky lottery choice	2.828	(1.507)	2.988	(1.583)	2.510	(1.302)
Ambiguous lottery choice	2.643	(1.623)	2.372	(1.519)	3.000	(1.673)
Loss lottery choice	3.428	(1.632)	3.232	(1.584)	3.706	(1.700)
Patient choices (1 day delay, 1 month duration)	5.400	(3.347)	5.139	(3.203)	5.784	(3.563)
Patient choices (1 month delay, 1 month duration)	5.736	(3.737)	5.965	(3.625)	5.274	(3.945)
I(DRD4 7-repeat allele present)	0.372	(0.485)	–		–	
Fraction in savings	0.507	(0.355)	0.549	(0.342)	0.445	(0.369)
I(Pay credit card balance each month)	0.714	(0.453)	0.779	(0.417)	0.627	(0.488)
I(Take only needed money from ATM)	0.393	(0.490)	0.477	(0.502)	0.235	(0.428)
I(Use debit card for routine purchases)	0.671	(0.471)	0.732	(0.445)	0.569	(0.500)
I(Have overdraft protection)	0.421	(0.495)	0.477	(0.502)	0.314	(0.469)
I(Use automatic deduction)	0.243	(0.430)	0.232	(0.425)	0.259	(0.440)

Means and (standard deviations) reported

2 Methods

Our participants were drawn from the college community in Middlebury, Vermont. As listed in the top panel of Table 1, despite being mostly students, we do have some demographic variation in our sample. The mean age is 22.5 years but it varies from 17 to 67. Approximately half the sample was female, about three-quarters described themselves as white, 11% had already finished college and 55% had annual household incomes between $25,000 and $150,000. Of the 140 people who participated, 125 were students, 12 were staff, 2 were faculty and 1 person was not directly related to the College. On average, the participants earned $22.43 for a session that lasted approximately 1 hour.[2]

The first part of the experiment was designed to gather risk attitudes.[3] According to Harrison and Rutström (2008), using ordered lottery sequences has been a standard way to elicit risk attitudes since the influential work of Binswanger (1980, 1981). Our basic choice structure is a modification of the ordered sequences introduced in Eckel and Grossman (2002, 2008) and used more recently by Garbarino et al. (2011). Each participant made three risky choices in the same order. For each choice, participants were shown a ring of six possible binary lotteries and told to pick one while thinking

[2]The instructions for the experiment appear in the methods Appendix.

[3]The experiment and survey were computerized and coded in zTree (Fischbacher 2007).

of the lotteries as representing opaque bags containing five high value balls and five low value balls, from which one ball would be chosen randomly. To minimize any problems that the participants might have with assessing probabilities (Kahneman et al. 1982), the likelihood of good and bad outcomes were equalized. Figure 2a displays the first choice which was designed to gather baseline risk attitudes. Here the payoffs for each 50–50 lottery were chosen so that both the expected payoff and the variance in payoffs increase in the clockwise direction around the ring. However, this pattern is violated as one moves from the \$4|\$91 lottery to the \$0|\$92 lottery. Here the expected value decreases as the variance continues to increase.[4]

After picking one of the lotteries from the first ring, participants made choices from two more rings where the setup was slightly altered. In the second, ambiguity, task displayed in Fig. 2b, the possible outcomes of the lotteries were the same but the chances of either the good or bad outcome were uncertain. Instead of six bags with five high and low value balls for sure, participants were told to think of each bag as having two high value balls and two low value balls for sure, but they were not told the distribution of the remaining six balls. This meant that the probability of the good outcome was uncertain; it was somewhere between 2/10 and 8/10. The ambiguity task was designed to see if probability uncertainty would cause 7-repeat participants to change their behavior compared to the baseline.

In the third, loss, task motivated by prospect theory (Kahneman and Tversky 1979), participants began with an endowment of \$50 and then chose from the six lotteries in Fig. 2c. As one can see, if you add \$50 to each payoff, you get back to the baseline Fig. 2a. Therefore the only change is the framing of the decision problem. The purpose of the loss task was to investigate whether 7-repeats would react differently compared to the baseline when losses are possible.

No feedback was given until after making all three lottery choices. The participants were then reminded of their choices, one at a time, and asked to click a button to have the computer randomly choose an outcome. The payoff from this part of the experiment was the sum of the three outcomes.[5]

In the second part of the experiment, we elicited time preferences using a standard procedure in which participants choose between an earlier payment $\$x$ and a delayed payment of $(1+i)x$ where $i > 0$. There were two blocks each consisting of ten choices (illustrated in Table 2) that involved an increase in i which varied from 25 to 250%. While these rates seem high, they are consistent with previous findings (Frederick et al. 2002) and, in this context,

[4]Following Holt and Laury (2002), we can use the constant relative risk aversion utility function, $U(x) = (x^{1-r})/(1-r)$ to evaluate the specific risk attitudes at which people should be indifferent between any two neighboring lotteries. Picking \$33|\$33 indicates extreme risk aversion, $r > 1.77$. Picking \$25|\$47 indicates $0.82 \leq r \leq 1.77$, \$18|\$62 indicates $0.48 \leq r \leq 0.82$, \$11|\$77 indicates $0.28 \leq r \leq 0.48$, \$4|\$91 indicates $0 \leq r \leq 0.28$, and picking \$0|\$92 indicates $r < 0$ or risk seeking behavior.

[5]The exchange rate for the experiment was one lab dollar equaled ten cents.

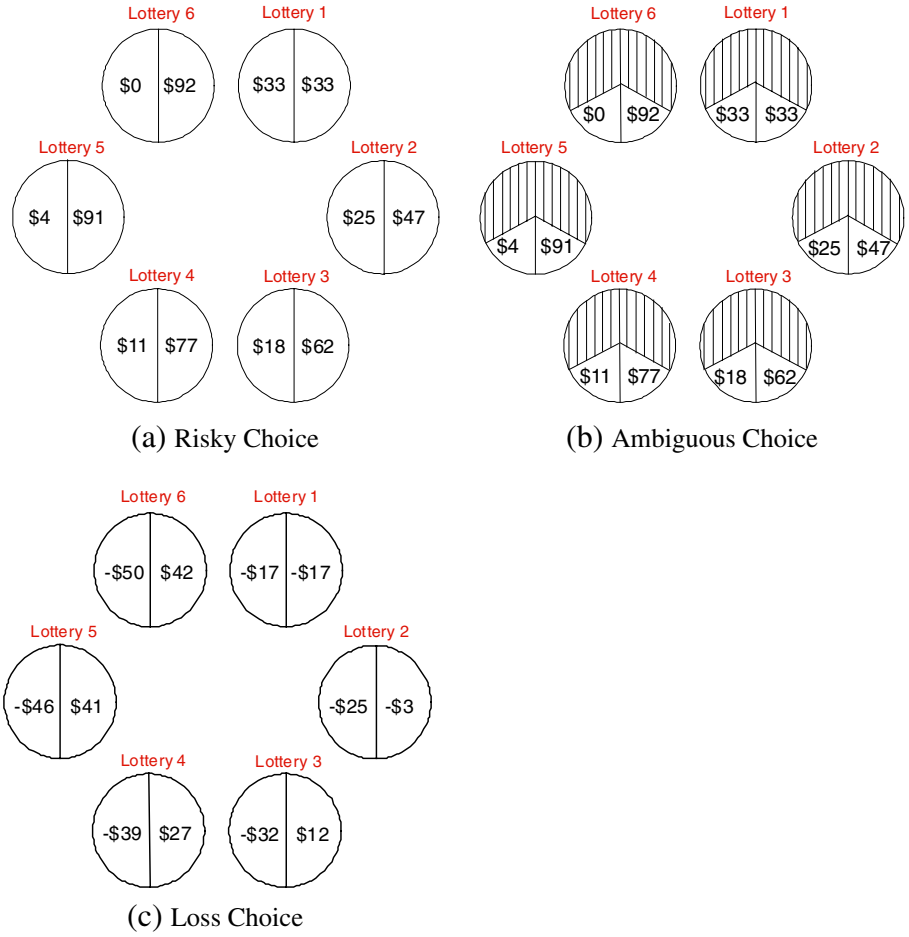


Fig. 2 Representations of the three lottery choice tasks. Participants were asked to pick one lottery from each ring. In panel **a** the line bisecting each circle indicated that each outcome was equally likely. In panel **b** the shading indicated that the decision-maker would not know exactly what the probability of the high and low outcomes would be when choosing. The lotteries in Panel **c** changed the frame of the task to include the potential for losses

we are mostly interested in the variation in responses, not their levels. The difference between the two blocks was the timing of the payments. In the first block, participants choose between \$50 tomorrow and $(1 + i)50$ in one month and in the second block they choose between \$50 in a month and $(1 + i)50$ in two months.[6]

[6]To prevent any confounding effects of trusting that one would be paid in the future, we implemented the shortest possible front end delay in the first block (Coller and Williams 1999) and to equalize the transactions costs across the two blocks, we paid everyone using the postal service. Middlebury is small enough that local letters posted on one day are delivered on the next.

Table 2 Choice in the time preference experiment

Choice	Early amount	Delayed amount	Annual rate	Annual effective rate
1	50	51.04	0.25	0.28
2	50	52.08	0.50	0.63
3	50	53.13	0.75	1.07
4	50	54.17	1.00	1.61
5	50	55.21	1.25	2.28
6	50	56.25	1.50	3.11
7	50	57.29	1.75	4.12
8	50	58.33	2.00	5.36
9	50	59.38	2.25	6.86
10	50	60.42	2.50	8.69

Note: In the first block, these ten choices (between the early and delayed amounts) were made in the context of recieving the early amount tomorrow and the delayed amount in one month. In the second block, the choices were the same but the early amount came in one month and the delayed amount came in two months

We implemented these two blocks to allow for time-inconsistent preferences. A standard, exponential, discounter would be consistent and make the same number of patient choices in the two blocks. However, quasi-hyperbolic discounters are time-inconsistent in that they are present biased and will act more impatiently now than they will when making choices for their future selves (Angeletos et al. 2001). In our setup, quasi-hyperbolic discounters are expected to make fewer patient choices in the first block than the second. At the end of the twenty choices in the two blocks, the computer randomly picked one and reported the outcome to the participant.

After the experiment was completed, the participants completed a brief survey. The survey began by asking for some typical demographic data (e.g., age, gender, ethnicity, schooling attainment, household income) and then asked about the financial decisions made by the participants. In each case, the decisions were such that risk attitudes and impatience could play a role. They were asked about their experiences with credit cards (e.g., whether or not they paid the balance each month), the banking system (e.g., whether or not they used automatic deductions to pay their bills), insurance and about any financial reserves set aside for emergencies.

Before receiving their final payoffs, the participants were asked to provide a genetic sample.[7] Because of recent technological innovations, extracting these samples is much easier and less intrusive than it used to be. Even ten years ago the primary sampling method was drawing fresh blood. However, now DNA sufficient for genetic analyses can be obtained from less invasive samples such as sloughed cheek cells. Instead of actively swabbing the inside of one's mouth for a sample, cells can be gathered from a buccal wash via swishing fluid from check to cheek for just a short time (Feigelson et al. 2001). Each participant was given a 15 ml centrifuge tube that contained approximately 10

[7]All our procedures were approved by the appropriate institutional review boards.

ml of Scope™ mouthwash, a sterile straw, and a napkin. At the same time, all the participants held the mouthwash in their mouths and lightly swished it from cheek to cheek for one minute. They then used the straws to put the samples back into the centrifuge tubes. All samples were later centrifuged to pellet the sloughed buccal cells from which DNA was extracted using the Maxwell®16 System (Promega).

3 Genes and observed preferences

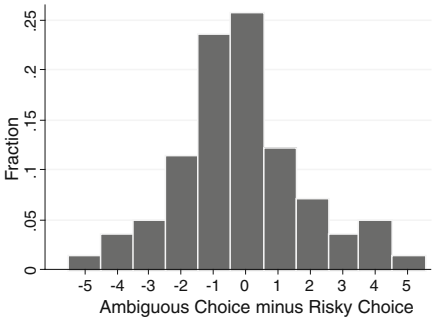
Before jumping directly to an analysis of whether genetic polymorphisms can predict responses in our risk and time experiments, we first present overall summary statistics from the experiment in the middle panel (and first column) of Table 1. The lotteries are numbered one through six where one is the safe \$33|\$33 choice (i.e., where one was sure to earn \$33) and six is the risk-seeking \$0|\$92 choice (i.e., where the participant had an equal chance to earn \$0 or \$92). Although all the lotteries are chosen to one degree or another, in the risky choice situation the modal choice was the second \$25|\$47 lottery and, on average, the third \$18|\$62 lottery is chosen. Compared to the risky baseline, in the ambiguity task, people tend to make more conservative choices, on average. Here the modal choice moves to the safe \$33|\$33 lottery. Interestingly, the average participant deviates in the opposite direction when faced with possible losses. In this measure the average choice moves closer to the −\$39|\$27 lottery (i.e., the analog of \$11|\$77) and the mode moves so that there is a tie between the fourth and fifth choices. While the overall difference between mean choices in the risky and ambiguous choices is not significant ($p = 0.27$), the differences between the loss and risky choices is highly significant ($p < 0.01$).[8]

Considering patient choices in the two discounting decision blocks, the first thing to report is that most of our participants made consistent choices: only 1% of our participants switched between waiting and not waiting more than once in the one day delay block and only 3% did so in the one month delay block. Further, when a one day front-end delay is imposed participants make an average of 5.4 patient choices (implying an average discount rate of 115%). As one might expect of quasi-hyperbolic discounters, the number of patient choices increases to 5.736 when the front-end delay is increased to one month (here the implied average discount rate is 106%); however, the overall difference is not significant ($p = 0.16$).[9]

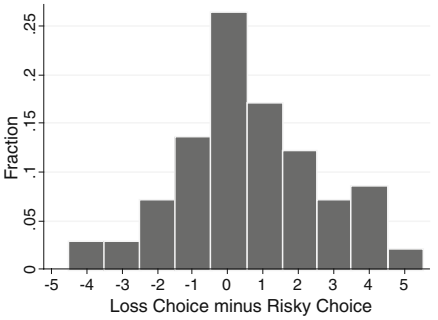
[8]Listed p-values are the result of two-tailed t-tests.

[9]We continue to work with the number of patient choices for two reasons. First, because our participants were so consistent, there is little to be gained from maximum likelihood methods. Second, like others we interpret our data conservatively in that, while we think of our procedures as eliciting good proxies of time preferences, it is not clear that we capture inherent discount rates, per se. This second point also explains why we number our lotteries instead of using the implied coefficients of relative risk aversion in our analysis.

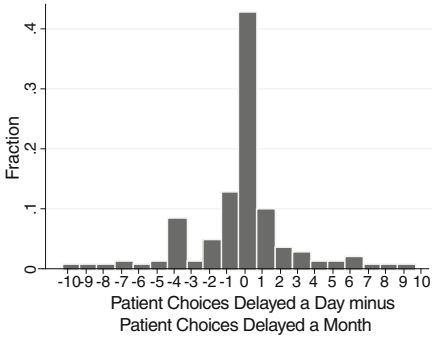
The individual-level differences that interest us are better depicted in Fig. 3 where we present histograms that record the within subject differences in choices between our treatments. In panel (a) we subtract the lottery number chosen in the risky baseline from that chosen in the ambiguous task to get a sense of how much less or more risk one is willing to accept when the odds are uncertain. Here for example, negative integers indicate by how many gambles the participant moved clockwise when the odds were ambiguous compared to the risky baseline. In panel (b) we do something similar to measure the difference in behavior when losses are possible. Here we subtract the risky baseline from the number of the lottery chosen in the loss task and negative numbers now indicate by how many gambles the participant moved clockwise because of potential losses. Lastly, in panel (c) we record the results of subtracting the number of patient choices made when the delay was a month from the same number when the delay was a day. This gives us a sense of how discounting changes with the time horizon.



(a) Comparing Ambiguity to Risk



(b) Comparing Loss to Risk



(c) Comparing Tomorrow and One Month

Fig. 3 Histograms of the differences in behavior between tasks. Panel **a** graphs the ambiguity choice minus the risk choice so that positive values indicate taking more risk under ambiguity, panel **b** graphs the loss choice minus the risk choice so that positive values indicate taking more risk when losses are allowed, and panel **c** graphs the difference in patient choices between the block with the earliest payment tomorrow and the block in which the earliest payment is in one month

Continuing with time preference, in panel (c) we see that many people are consistent with the exponential discounting model in that they make the same number of patient choices in the two blocks. At the same time, we see a considerable amount of time-inconsistent choices. Those people who make fewer patient choices now than when considering their future selves (i.e., they are quasi-hyperbolic) are characterized by negative differences in Fig. 3c; one-third of our participants fall into this category. The remaining one-quarter of our participants are time-inconsistent in a way that has not been discussed in any detail in the literature until very recently (e.g., Sayman and Öncüler 2009). Instead of being more patient when considering their future selves, these people are less patient: they discount outcomes more the further in the future they place themselves. In this sense they are "anti-hyperbolic".

In panel (a) of Fig. 3 we see that a considerable number of people (i.e., 45%) behave as predicted by Ellsberg (1961) and are more conservative when they do not know the distribution of outcomes for sure (i.e., the difference is negative). The histogram in panel (b) is also asymmetric because 47% of people are relatively more risk-seeking when losses are possible. These broad results give us confidence in our procedures because they seem to have replicated many of the stylized facts of the risk and impatience literatures.

Returning to Table 1, we see that 137 of the 140 buccal samples yielded sufficient DNA to genotype the participant.[10] Of these 137 individuals, 51 (i.e., 37%) had at least one 7-repeat DRD4 allele. Considering first our baseline risky task, we find that 7-repeats do not appear more risk-seeking than 4-repeats. If anything, they seem a little more risk averse ($p = 0.07$). Seven-repeats do, however, pick riskier lotteries when the probabilities become ambiguous ($p = 0.03$) and when losses are possible ($p = 0.10$). While the first result seems contrary to the conclusions about risk reported in Kuhnen and Chiao (2009) or Dreber et al. (2009), the tasks used in these two studies were actually more similar to our loss task and considering this, our marginally significant loss result does replicate this work to some extent.

Considering the discounting tasks, there are no differences in the number of patient choices picked in the first, one-day delay block ($p = 0.28$) and although the 7-repeats do make fewer patient choices in the one-month delay block (5.27 versus 5.96) the difference is not significant ($p = 0.30$). In this sense we find no evidence of 7-repeats being quasi-hyperbolic discounters.

Despite few significant results when looking at the levels of our measures, there are a number of highly significant results when one looks at how behavior changes (within subjects) between the measures. Figure 4 summarizes our main results. Here we examine how the differences calculated for Fig. 3 correlate with the presence of the 7-repeat allele. In other words, we report differences in differences. In panel (a) we record the mean difference between the ambiguous choice and the risky choice for those who have the 7-repeat allele and those who do not. In this case a mean below zero indicates a general

[10]The details of the genotype amplification procedures are in the methods Appendix.

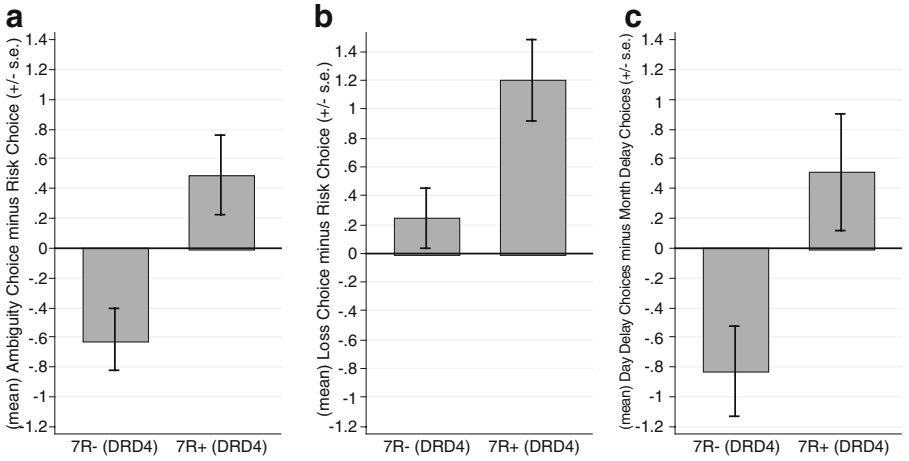


Fig. 4 Mean measure differences by DRD4 polymorphism. 7-repeat gene holders (7R+) are more risk seeking under ambiguity in Panel **a** ($p < 0.01$), more risk seeking with losses in Panel **b** ($p < 0.01$), and less patient when considering their future selves in Panel **c** ($p < 0.01$)

preference to take on less risk when the odds are ambiguous and a positive mean implies taking on more risk in an ambiguous situation. In panel (b) we look at mean differences between the loss choice and the risky choice and a positive mean indicates an overall preference to take on more risk when losses are possible. Finally, in panel (c) we examine whether the presence of the 7-repeat allele predicts being a quasi-hyperbolic discounter (i.e., a negative mean) or an anti-hyperbolic discounter (i.e., a positive mean).

As one can see in Fig. 4, 7-repeats behave significantly less conservatively in the face of ambiguity and losses and are more likely to differentially discount their future selves. The mean measure of the difference due to ambiguity (i.e., the difference between the ambiguous choice and the risky choice) is positive for 7-repeats, negative for the others and the difference (in differences) is highly significant ($p < 0.01$). Likewise, the shift in behavior when losses are possible (loss choice minus risk choice) is significantly more positive for the 7-repeats ($p < 0.01$). In other words, they appear more loss averse in the traditional sense. As for the number of patient choices, one can see from Fig. 4 that the 7-repeats are more likely to be inconsistent in the anti-hyperbolic direction while the others tend to be quasi-hyperbolic, on average. This difference is also highly significant ($p < 0.01$).

In addition to simple t-tests, we also conducted a regression analysis of the relationship between the genotypes and the experimental behavior. The results are listed in Table 3. Because none of the scales used to identify the lotteries or the patient choices are cardinal, we used the ordered probit estimator with robust standard errors. We also estimated the coefficients with and without a full set of controls for all the demographics summarized in Table 1. The results in Table 3 confirm what we saw in Fig. 4: The correlations between genotype

Table 3 Regressing observed preferences on DRD3 long allele (7R)

	Ambiguity − Risk		Loss − Risk		Day − Month	
I(DRD4 − 7R+)	0.597***	0.580***	0.506***	0.456**	0.368**	0.453**
	(0.175)	(0.181)	(0.185)	(0.198)	(0.175)	(0.188)
With controls	No	Yes	No	Yes	No	Yes
Wald Chi-sq	11.65***	18.26**	7.45***	15.07*	4.43**	8.17
N	137	137	137	137	137	137

Note: Ordered probit regressions with robust (standard errors). The controls include age, gender, ethnicity, subject pool, education and household income. The discounting estimate also controls for risk choices. Star indicate significant at the * 10%, ** 5% and *** 1% levels

and behavior are highly significant and robust to the inclusion of potential demographic covariates.[11] Specifically, in the first two columns of Table 3 we see that the coefficient on the indicator for the presence of the 7-repeat allele is positive and highly significant confirming that 7-repeats choose relatively more risk than 4-repeats when the situation is ambiguous. We also see that adding demographic controls has no effect on this estimated effect. The coefficient on the indicator is also positive and highly significant in the second two columns of Table 3 which confirms that 7-repeats also take on relatively more risk when losses are possible. As with ambiguity, column 4 suggests that the loss effect is diminished only slightly when we control for observables. To round out the analysis, the positive and significant coefficients in the last two columns of Table 3 indicate that 7-repeats make more patient choices when the delay is only one day than when it is a month.[12]

In line with the behavioral genetics literature, we find that participants who possess the 7-repeat allele polymorphism act as though they seek novelty in that they are more likely to incur financial risk when the situation is ambiguous or losses are involved than when the odds are known and the outcomes are all positive. They also appear impulsive in a different sense than the quasi-hyperbolic discounters: 7-repeats are not biased toward the future; they are biased towards the present.

[11] Given the results of Burks et al. (2009) who show that higher IQ is correlated with being closer to risk neutral and more patient, one might worry that our regressions have omitted important controls like cognitive ability or perhaps "optimism" which might affect one's subjective assessments of the odds of the gambles. However, there is no evidence that DRD4 is correlated with intelligence (Kebir et al. 2009) and optimism is much more likely to correlate with serotonin than dopamine (Fox et al. 2009).

[12] To follow up on an excellent comment made by our referee, we also stacked the 20 time preference choices for each participant and ran another set of regressions with individual random effects. One of the major advantages of doing this was that we were able to get a precise estimate of how much less willing 7-repeats are to wait when the front-end delay expands to a month. We find that anti-hyperbolic 7-repeats are 5% less likely to wait ($p = 0.01$) and quasi-hyperbolic 4-repeats are 8% more likely to wait ($p < 0.01$).

4 Genes and financial choices

In the post-experimental survey we asked participants several questions about their financial decision-making. We focus here on the responses to the more concrete factual questions although analyses of some of the other, more hypothetical, questions yield similar results.[13]

The responses to the six questions considered are summarized in the bottom panel of Table 1.[14] In the first row are the responses to a question which asked for the division of the respondent's cash between their checking and savings accounts. On average, people allocate half of their funds in the two accounts. The second question, summarized in row 2, was about credit card use. Participants were asked if they pay the minimum each month, pay as much as they can each month, or pay the total amount due each month. Overall, 71% of people stated that they pay the balance due each month. In row 3 we see that 40% of the participants only withdraw the amount of money that is immediately needed from the ATM while the remaining 60% withdraw more. We find, in row 4, that 67% of participants tend to use their debit cards (instead of their credit cards) for routine purchases. In the last two rows of Table 1 are the results of asking whether participants use banking services that could reduce the chances of incurring large fees. In row 5 we see that 42% of people pay a small fee for overdraft protection on their checking accounts and in row 6 that only 24% use an automatic deduction service to make sure that monthly bills are paid on time.

In Fig. 5, we present the mean responses to the individual survey questions by genotype. The overall pattern is striking: 7-repeats are less likely to make the safe, patient choice in all but the last, automatic deduction, context. Specifically, 7-repeats hold fewer funds in savings ($p < 0.10$) and are less likely to pay the balance on their credit cards each month, ($p < 0.05$), to withdraw only the needed amount of money from the ATM ($p < 0.01$), to use their debit cards instead of their credit cards ($p < 0.05$) and to purchase overdraft protection ($p < 0.10$). Not only is the fact that a pattern arises interesting, it is also interesting that these results jibe nicely with our observed preference results in Fig. 4.

As a more complete check on these results, in Table 4 we regress survey responses on genotype with and without a full set of controls. Because the fraction of cash one holds in savings is bound by both 0 and 1, we use the Tobit regressor in the first two columns; however, for all the other estimates we report marginal effects from probit regressions. What is interesting here is

[13]However, not all the survey questions yielded interesting results: the size, in dollars, of one's ideal financial reserve, for example, was not predicted by genotype.

[14]The exact wording of each question is presented in the methods Appendix.

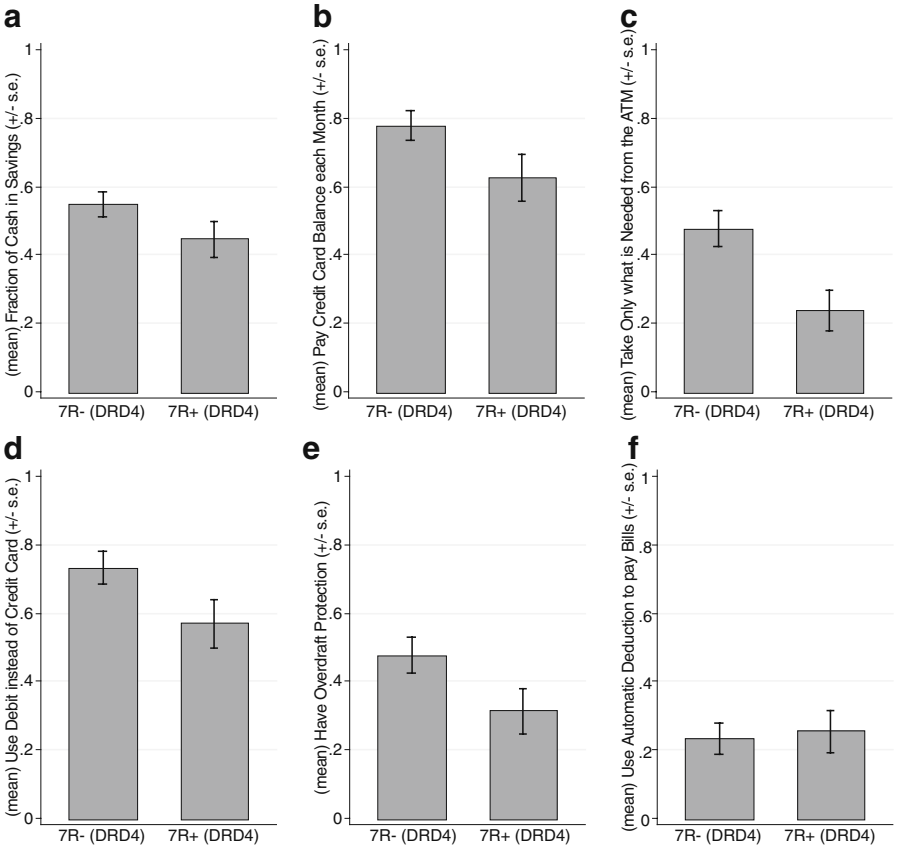


Fig. 5 Financial choices by DRD4 polymorphism. In Panel **a** 7–repeat gene holders (7R+) hold fewer funds in savings ($p < 0.10$). Panel **b** indicates 7-repeats are less likely to pay the balance on their credit cards ($p < 0.05$). Panel **c** shows that 7-repeats are less likely to withdraw only the cash they need from the ATM ($p < 0.01$). In Panel **d** 7-repeats are less likely to use their debit (instead of credit) cards when making routine purchases ($p < 0.05$). Panel **e** indicates 7-repeats are less likely to purchase overdraft protection ($p < 0.10$). Panel **f** shows no difference in the unconditional likelihood of using automatic deduction to pay bills

that not only do the significant differences remain (or become larger) when we control for the demographics, the marginal effects are also substantial. From the first two columns we see that 7-repeats keep between 14% and 19% less of their cash in savings, they are between 15% and 21% less likely to pay their credit card balances, they are between 15% and 24% less likely to take out only what is needed from the ATM, they are approximately 16% less likely to use their debit cards, and they are between 16% and 20% less likely to have overdraft protection. That said, the 7-repeats also appear to be somewhat sophisticated—they are 13% more likely to use automatic deductions to pay their bills.

Table 4 Regressing financial choices on DRD4 long allele (7R)

I(DRD4 – 7R+)	Fraction in savings		I(Pay CC balance)		I(Take what's needed from ATM)		I(Use debit instead of credit card)		I(Have overdraft protection)		I(Use automatic deduction)	
	−0.138* (0.082)	−0.187** (0.079)	−0.152* (0.081)	−0.210** (0.088)	−0.241*** (0.080)	−0.152* (0.089)	−0.164** (0.084)	−0.158* (0.089)	−0.163* (0.085)	−0.199** (0.089)	0.022 (0.076)	0.135* (0.084)
With controls	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
F or Wald Chi-sq	2.89*	3.09***	3.57*	17.52**	7.85***	31.29***	3.81**	13.31*	3.49*	9.84**	0.09	21.05***
N	137	137	137	137	137	137	137	137	137	137	137	137

Note: Tobit or probit regressions with robust (standard errors). Marginal effects reported. The controls include age, gender, ethnicity, subject pool, education and household income. Stars indicate significant at the * 10%, ** 5% and *** 1% levels

5 Discussion

Compared to previous work, our results are mixed. While we do not find that 7-repeats are significantly more risk seeking in a more traditional task that only involves gains, when losses are possible we find, as others have, that there is some marginally significant evidence that 7-repeats are willing to incur more risk. We also do not find that 7-repeats make fewer total patient choices, a result consistent with the previous literature. At the same time we have plenty of significant results that seem to arise more subtly in the within subject differences between measures. The question then becomes whether we can modify the standard choice paradigm to account for the influence of dopamine receptor gene variation in a way that allows us to organize these results, including those where significant links to baseline risk and discounting have been found. Of course this is an exercise in *ex post* theorizing but, nevertheless, to move forward it will be helpful to provide some theoretical structure that can both organize some of the current results and offer new hypotheses that can be examined in future experiments.

Our representation is an admittedly simple first step that can, no doubt, be extended in many interesting directions.[15] However, while simple, the logic is parsimonious in that the addition of just one feature provides interesting predictions. To make our representation compelling we had to determine a critical neurobiological feature that accounts for the phenotypic differences between 4- and 7-repeat allele carriers and develop it in a way that makes sense economically. We then ask whether the addition of this feature can predict the systematic differences in behavior found in our experiment and those of others. Most importantly, the resulting construction also provides new, testable, hypotheses.

The neurobiological difference that researchers return to again and again is that 7-repeats need more stimulation to feel the same "tingle" of dopamine (Asghari et al. 1995). In other words, small changes in stimulation do not generate enough dopaminergic activity to register a state change (pleasure or displeasure) in the 7-repeat brain and so the individual doesn't notice. As a result, small stimuli have little or no effect on 7-repeats. To illustrate this consider one recent study, in which brain researchers found that sufferers from Parkinson's disease, which has been linked to abnormalities in the dopaminergic system, were half as likely to notice changes in auditory stimulation (Lewald et al. 2004). The "just noticeable differences" of these people were much larger than for the controls.[16] This suggests one way to represent the effect of allelic differences in dopamine receptors: because 7-repeats show no response when stimuli do not exceed their just noticeable thresholds, they may

[15] A promising recent direction is offered by Caplin and Dean (2008).

[16] The notion of one's "just noticeable difference" has a long tradition in psychology and physiology. Imagine two bags filled with the same number of marbles. If you were asked to hold both, your JND is the number of marbles that one could secretly add to just one of the bags before you noticed a difference.

also show no response to financial stimuli that fall below a certain threshold. Put differently, below their thresholds we assume that individuals do not notice any change in utility and therefore 7-repeats are indifferent among these outcomes.

Intuitively, this characterization makes sense. Many people would not stop to pick up a penny, or even a dime but they would pick up a dollar. This is not because they are cognitively impaired, they know the difference in values, and it may not be because of the cost associated with bending over. A simple explanation is that the dollar yields stimulation over one's threshold and the two coins do not so they are ignored or both treated like a penny. Certainly there will be heterogeneity in thresholds and as a result we make the following two assumptions. First, we assume that although everyone can differentiate between any two payoffs and would, all else equal, value certain immediate payoffs more (as discussed in Dickhaut et al. 2003; and Burks et al. 2009), when the payoffs fall below one's threshold, the differences are too small to notice and they are all assigned the same utility. Second, we assume that, on average, carriers of the 7-repeat DRD4 allele have higher thresholds than 4-repeats and for the sake of simplicity we set the threshold of 4-repeats to zero. Hence, the utility function for 4-repeats is ordinary but for 7-repeats it is represented as:

$$U^{7R}(x) = \left\{ \begin{array}{c} U(x) \text{ if } x > x^{7R} \\ U\left(x^{7R}\right) \text{ otherwise} \end{array} \right\}$$

where x^{7R} is the 7-repeat stimulation threshold and $U(x^{7R})$ is the value assigned to all payoffs, x, that fall short of the threshold (Aleskerov et al. 2007).

In some regards, this formulation is motivated by the discussion of editing prospects in Kahneman and Tversky's original work (1979). However, while the process of editing outcomes and probabilities appears somewhat cognitive in the original, our supposition is that the normalization of small stimuli is mostly automatic, especially for those with high thresholds. In this sense our formulation is closer to Ng (1975) who considers decision-makers with finite sensitivities. Our specification is also reminiscent of the work of Rubinstein (1988) and Leland (1994, 2002) in that aspects of the decision that differ little carry less weight than they might in the classical model; however, our approach differs in that we normalize small differences to one low utility level instead of assuming that small differences cause people to focus on other aspects of the decision.

Now consider the implications of a 7-repeat payoff threshold for risky decision making. On the left side of Fig. 6a we have the standard representation of the choice between accepting a lottery which one values according to its expected utility (EU) or having the expected value (EV) of the lottery for sure. The latter option results in utility level $U(EV)$. Without a payoff threshold, 4-repeats choose to reject the gamble because diminishing marginal utility implies that $U(EV) > EU$. The same gamble is perceived differently by the 7-repeats (on the right of Fig. 6a). Because all the payoffs up to x^{7R} are assigned the same low level of utility, the function is initially flat and this introduces

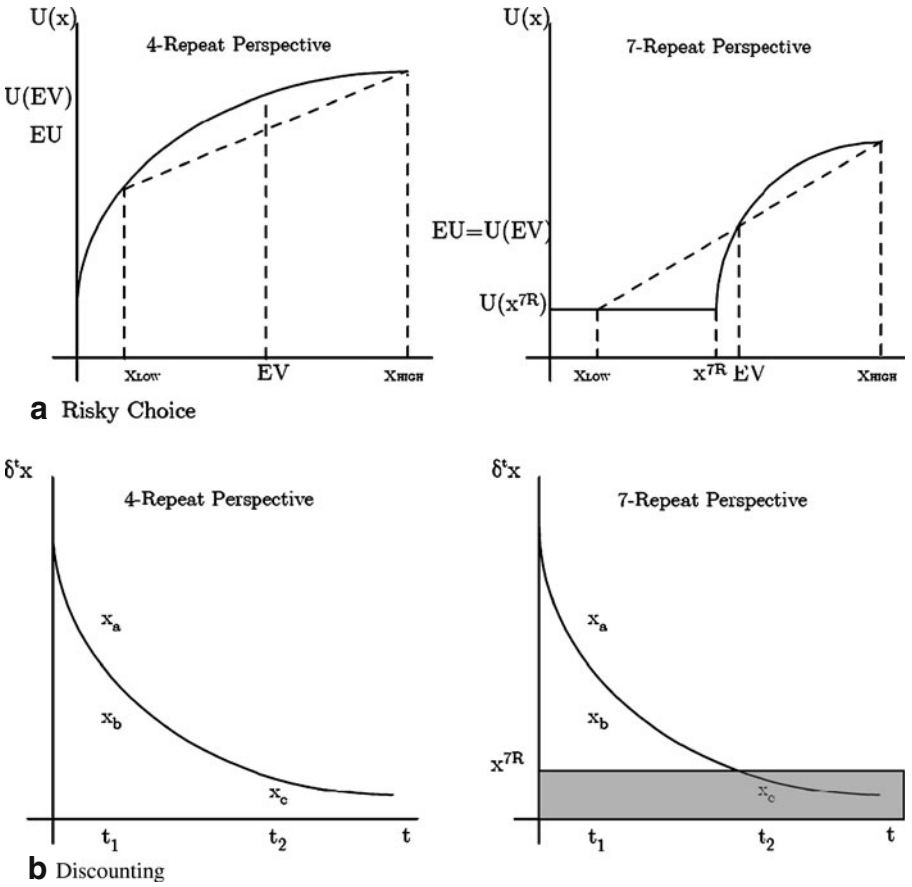


Fig. 6 Choice behavior with threshold utility. 7-repeat allele carriers are subject to a stimulation threshold (x^{7R}) under which all payoffs are assigned the same utility level. Panel **a** analyzes the implications of thresholds on risky choices and Panel **b** examines discounting decisions

some convexity to the choice. As drawn, the 7-repeat appears risk neutral (i.e., $U(EV) = EU$) and therefore would consider taking the gamble while the 4-repeat would not. Behavior separates further for those lotteries that generate lower EVs . This set of lotteries will be accepted for sure by the 7-repeats (because now $EU > U(EV)$ for them) and rejected by the 4-repeats. However, behavior does not completely bifurcate: lotteries with EVs above that drawn in the figure will be rejected for sure by both types. In short, the threshold adds the sort of convexity to the problem that suggests that in some situations 7-repeats should appear less risk averse.

We can also make simple predictions about how ambiguity and the potential for losses might interact with the 7-repeat payoff threshold. Evidence from a field experiment with more than 3,000 participants suggests that people react conservatively to ambiguous gambles (Cardenas and Carpenter 2009).

Compared to their choices in a baseline risky task, on average, people appear more risk averse in a task where the probabilities are ambiguous. The obvious interpretation is that people lower their subjective assessments of the probability that the good outcome will occur in ambiguous gambles.[17] This reaction to ambiguity should result in us observing even fewer risk averse choices among 7-repeats because a perceived reduction in the chances of a good outcome will reduce the EV of the gamble and, ceteris paribus, increase the chances that the EV will fall below the critical value drawn on the right side of Fig. 6a. A similar prediction can be made for lotteries that involve losses as well as gains. Here it is not the reduced probability of the good outcome that pulls down the EV, it is the substitution of a loss for the previously low but positive payoff. To be clear, this simple logic predicts that for substantial positive stakes 7-repeats will make choices similar to 4-repeats but when the expected value of the gamble begins to fall (because the stakes are low, substantial losses are introduced or the odds are sufficiently ambiguous) 7-repeats will appear generally less risk averse than 4-repeats.

What are the implications of adding a 7-repeat payoff threshold to the basic intertemporal choice problem? In Fig. 6b we depict the choice problem from both perspectives (i.e., with and without a threshold). Each allelic type is faced with the same decision to consume a smaller payoff now or wait for a larger delayed payoff. We assume that they both employ the standard exponential discounting function (δ^t where $0 \leq \delta \leq 1$). For any payoff above the threshold, the two types make the same choices. For example, if offered the choice between x_a now and x at time period t_1 (where $x_a < x$) both would take the sooner payoff because $x_a > \delta^t x$. Likewise, both would decide to wait if instead x_b was offered now. However, perceptions change for the 7-repeats when payoffs fall below x^{7R}. Here, for example, the 4-repeats reject x_c and wait t_2 periods for x while for the 7-repeats, because both payoffs fall below the threshold and are assigned the same utility level, don't—there is no point in waiting for what is perceived to be the same low payoff.

The important thing to notice is that only the more distant payoffs, because they are discounted more heavily, will fall below the 7-repeat's threshold and therefore the prediction is more specific than a general reduction in patience. During any time period in which the discounted payoff is above the threshold, the 7-repeats should make the same choices as the 4-repeats. There is no reason to assume that they use different discounting functions. Behavior should only separate for choices involving the more distant future. It is here that the 7-repeats will appear less patient.

As one can see, a purposefully simple first pass at how one might begin to think about incorporating neurobiological differences in the standard choice paradigm captures a number of the results of the current, and previous experiments. While there are many obvious directions in which a more formal

[17] This is also a common starting point for many theories of ambiguous choice (e.g., Gilboa and Schmeidler 1989).

theoretical treatment could proceed,[18] it is equally important that this formulation suggests new hypotheses that can be examined in future experiments. With respect to time, for example, the difference between 4- and 7-repeats should be a function of stakes if the threshold formulation is correct. For an absolute threshold as drawn in Fig. 6b, as the stakes increase the "anti-hyperbolic" behavior of 7-repeats should be pushed further into the future. In the current experiment we find significant results when the delay is one month but if the stakes were raised substantially it would take longer for the value to decay below the same threshold. The same is true of risk. Returning to Fig. 6 one can see that if both lottery payoffs are above the threshold, then the 7-repeat should make the same choice as the 4-repeat. Likewise, when both payoffs are sufficiently low only the 7-repeat becomes risk neutral. Lastly and perhaps more definitively, given the right configuration of payoffs and probabilities, one should see the same 7-repeat who is risk averse at high stakes and risk neutral at low stakes being risk seeking when just one payoff is below the threshold.

6 Concluding remarks

Our experiment and results might be an important early step in linking the dynamic behavioral genetic literature to economics. First we show that preferences for risk and time, which are the cornerstones of many economic theories, can be linked to both the existing research literature on dopaminergic function and the dopamine receptor genetic polymorphisms themselves. Previous research suggests that certain genes associated with a muted response to dopamine predict exploratory behavior. We have shown that the economic extension of this behavior is reduced sensitivity to risks when situations are ambiguous or when losses are possible and to be less concerned with the possible implications of future decisions.

The potential extensions of this work are broad-ranging. For instance, can other important decisions like migration (Chen et al. 1999) that are confounded by ambiguity and possible losses be understood through the lens of sensation-seeking and explained in terms of genetic predispositions? Are other important education, career, and retirement choices based on these sorts of reactions to ambiguity, losses, and the time horizon of decisions?

We can also imagine another, much more practical contribution of gathering genotypes. Given the continued interest in modeling and estimating the impacts of risk and time preferences on outcomes and choices, it becomes essential to find valid instruments to unlock the causal nature of these relationships.

[18]For example, one might consider a model in which utility is simply less concave for 7-repeats. While this would make some of the same predictions concerning risk, without auxiliary assumptions, it makes the opposite predictions concerning discounting. Most importantly, however, we feel that our formalization is consistent with the dopamine muting and the just noticeable differences literatures.

A behavioral neurogenetics approach, as undertaken here, allows researchers to relate particular neurochemicals (e.g., dopamine, serotonin, oxytocin) to predictable behavioral tendencies (e.g., sensation-seeking, boldness, trust). Our results suggest that given due diligence has been done to identify the channels through which genetic differences may affect outcomes (i.e., no fishing expeditions allowed), the exclusion restriction might be satisfied almost as straightforwardly as the exogeneity restriction. In fact examples of this methodology are begining to appear in the literature (e.g., Ding et al. 2009 or Fletcher and Lehrer 2009).

Acknowledgements We thank Middlebury College and Binghamton University for funding parts of this research. We also thank the editor, an anonymous referee, Lorenz Götte, Douglas Krupka, Erin Krupka, Caitlin Myers and Corinna Noelke for constructive comments on earlier drafts of this paper. Valuable laboratory assistance was provided by Rita Spathis. Carpenter and Garcia were involved in all aspects of this project; Lum participated in formulating the research question, editing the manuscript, and by overseeing the genetics laboratory.

Appendix A Genotyping, experiment instructions and survey questions

A.1 The gene amplification procedures

The human DRD4 gene on chromosome 11 contains a 48bp variable number tandem repeat (VNTR) polymorphism in exon 3. Problems associated with consistent genotyping of the DRD4 VNTR region suggested the need for multiple PCR and electrophoresis runs for each sample to control for allelic dropout. Thus, the PCR reaction was modified to reflect the high GC content (see below) and all samples that were initially scored as homozygotes were reanalyzed with different starting template concentrations to unambiguously confirm genotypes. The PCR reaction consisted of 1x Q-Solution (Qiagen), 1x Buffer (Qiagen), 1 μM Primer 1 (5' GCGACTACGTGGTCTACTCG 3'), 1 μM Primer 2 (5' AGGACCCTCATGGCCTTG 3'), 200 μM dATP, 200 μM dTTP, 200 μM dCTP, 100 μM dITP, 100 μM dGTP, 0.3 units HotStar Taq (Qiagen), and 1 μl of DNA template, in a total volume of 10 μl. The PCR profile began with 15 min at 95°C for enzyme activation and denaturing of template DNA followed by 40 cycles consisting of 1 min denaturation at 94°C, 1 min annealing at 55°C, 1.5 min extension at 72°C, and finished with a 10 min extension at 72°C. Amplicons were electrophoresed through 1.4–2.0% agarose gels containing ethidium bromide and genotypes were determined by comparison with a 100 bp ladder.

A.2 The experimental instructions

A.2.1 Overview

Today's experiment will consist of three components. Your total payoff for the experiment will be your $5 show-up fee plus the sum of the payoffs

you earn in the different components (note that the exchange rate between experimental dollars and real dollars is \$E10 = \$1). We expect that you will earn approximately \$25, on average, and that the experiment will not last much more than an hour. Your participation is strictly confidential and once the data has been compiled any personal identifiers will be removed. Detailed instructions for each part of the experiment will appear on the computer screen at the beginning of the component.

A.2.2 Risk, Ambiguity and Loss

To motivate this part of the experiment, think of a bag containing ten balls. Like in billiards, each ball has a number written on it. These numbers represent dollar payoffs. To determine your payoff, you will pick among six bags that differ in the numbers written on the balls and then reach in and draw one ball from the chosen bag. In this sense, each bag represents a possible lottery for you.

You will make three decisions in which you choose one from a set of six bags/lotteries. Each of the lotteries will be represented by a circle and two numbers. The two numbers represent the two possible dollar payoffs for each bag/lottery. When you have made all three decisions, the computer will act out the lotteries that you have chosen and any proceeds from the lotteries will be added to your final payout.

Click the button below to start the first decision.

Decision one In the first set of six bags one bag has the same number written down on both sides of the dividing line which means that if you pick this lottery all the balls have the same number written on them and you will get this amount of money for sure. The other five bags/lotteries have five high value balls and five low value balls. Remember that each ball has an equal chance of getting picked so your chances of getting the high amount or the low amount are exactly the same. Pick a bag/lottery by clicking on the appropriate button to the right.

Decision two In the second set of six lotteries each circle has a shaded area which represents the fact that you do not know for sure the value of six of the ten balls in each bag. You know for sure that there are two high value balls and two low value balls but the other six balls can be either high or low value and you won't know for sure the final distribution until the end of the session.

However, as in the first decision, the first bag has the same number written on both sides of the dividing line which means that if you pick this lottery all ten balls have the same number written on them and you will get this amount of money for sure.

Remember that each ball has an equal chance of being picked so your chances of getting the high amount or the low amount will depend on the final mixture of balls. Pick the bag/lottery from which you would like to have a ball drawn by clicking on the appropriate button to the right.

Decision Three At the beginning of this decision your final payoff was increased by $50 but instead of lotteries in which your final payoff can only increase, you now must choose among six lotteries, some of which include potential losses.

In this case, the first bag has the same negative number written on both sides of the dividing line which means that if you pick this lottery all the balls have the same number written on them and you will lose this amount of money for sure. The other five bags/lotteries have five high value balls and five low value balls.

Remember that each ball has an equal chance of getting picked so your chances of getting the high amount or the low amount are exactly the same. Pick a bag/lottery by clicking on the appropriate button to the right.

A.2.3 Time

In this part of the experiment you will choose between two amounts of money. In each case, you will choose between a smaller amount of money and a larger amount of money. The choice seems obvious but it is not because if you choose the larger amount of money you will have to wait longer to receive it. In other words, your choice will be between a smaller amount of money which you will receive relatively soon and a larger amount of money that you will have to wait longer to receive.

The amounts of money and the amount of time you have to wait for the larger payoff change from one choice to the next so please consider each situation carefully. At the end of the experiment one of the choices that you have made will be picked randomly and you will actually be paid based on what you have chosen. This means that you will be sent (via mail) the chosen amount of money at the time you specified in your decision.

Click the button below to start making choices.

A.3 The survey

While we determine how much money we owe you, please complete a short questionnaire to be used in our analysis of the experimental data. The questionnaire should take less than 10 min to complete. All responses will be kept confidential and will not be stored with any personally identifiable information. By completing this survey, you consent to having this anonymous information used solely for purposes of academic research.

(1) How old are you?
(2) What is your sex?
(3) From which group were you recruited?
Student, Staff, Faculty, Not directly affiliated with the College
(4) Which of these racial/ethnic groups describes you best?
White/Caucasian, African-American, Asian-American/Asian, Latino/Hispanic, Other/Mixed

(5) How much schooling have you had?
less than High School, High School degree, some College, College degree, Graduate degree
(6) What is your annual household income?
less than $25,000, $25,001–$50,000, $50,001–$75,000, $75,001–$100,000, $100,001–$125,000, $125,001–$150,000, more than $150,000
(7) Consider your use of credit cards, do you:
pay the minimum each month, pay as much as I can each month, pay the total amount due each month.
(8) Considering all the money you typically have in your checking and savings accounts, how much is in the savings account (as a percentage, between 0 and 100, of the total)?
(9) Do you have overdraft protection on your checking account?
(10) Do you use automatic deductions to pay your bills?
(11) What do you think your credit rating (i.e., FICO score) is like?
(12) If you need to, imagine that you own a car. All cars need to carry "liability" insurance to cover hitting someone but they do not need to carry "collision" insurance to cover damage to one's own car. Do you (or would you) buy the collision insurance too?
(13) When you go to the ATM to get cash do you tend to get about the amount of money that you think you will need for your immediate needs or do you take out more so that you always have some cash in your wallet?
(14) When you are going on a trip, do you buy travel insurance which allows you to cancel a flight and re-book without a fee?
(15) About how much do you think that you need to have in savings for emergencies and other unexpected things that may come up (round to the nearest dollar)?
(16) When you make routine purchases which card are you more likely to use your credit or your debit card?
Please wait for the experimenter to call you to pay you for your participation. Your final payoff (in dollars and including any amounts you might actually receive in the future) from the experiment is:

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